Dear Dr. McNeil,

The revised version of the manuscript has been uploaded to the ACPD web site. We have revised the manuscript following the comments of both reviewers paying a particular attention to the suggestions of reviewer 1. Please find below our point-by-point reply (in blue) to the reviewer's comments (in black) and let us know if you have any further questions.

Best regards,
Georgiy Stenchikov

Response to Review 1

The authors present a case study of a dust storm over the Arabian Peninsula. Is is an application study, using the regional weather research forecast (WRF) model with a chemistry/aerosol module incorporated, to investigate the impact of a specific dust storm on the Arabian Peninsula and adjacent ocean regions, particularly the Arabian Sea and the Red Sea. The novelty of the study is limited to providing data on the effect of dust storms in this specific region, if the one case is taken as exemplary for dust storms generally. The paper is a solid work, though. It provides a systematic and thorough analysis of the dust storm event, which by itself is very interesting and a valuable contribution to science. The manuscript is well structured and well written. I have only a few minor comments and questions I would like to have taken into consideration before the study is published.

The Arabian Peninsula is one of the most important dust source regions, where effect of dust on all aspects of natural and societal processes is extremely large but yet not well quantified. In this study we tried to answer to some of the most important questions related to the dust mass balance, and the dust effect on radiation transport and nutrient balance in the Red Sea.

Minor Comments

1. Introduction: The introduction of the manuscript provides a very general overview on the role of dust aerosols for Earth's weather and climate. It could be shortened quite a lot, and still give a sufficient introduction and motivation for the presented research. Remove the parts on the general role of dust on a global scale. Focus on dust storms, what research has been done so far on modeling the regional impact of dust storms, and why a study, like the one presented by the authors, on the effect of a dust storm on the Arabian Peninsula is needed.

The Introduction section has been shortened as proposed:

Introduction, Section (1)
ACPD online version, P19183, L16 – P19184, L3: Text removed
ACPD online version, P19184, L10 – 12: Text removed
ACPD online version, P19185, L10 – 29: Text removed
ACPD online version, P19186, L8 – 11: Text removed
ACPD online version, P19186, L11 – 13: Text corrected (Revised manuscript: P3, L23 – 25)

2. Page 19185, lines 12-14: The authors write: "Sokolik and Toon (1999) and Claquin et al. (1999) showed that dust mineralogy is comprised of six main minerals: illite, montmorillonite, kaolinite, quartz, calcite and hematite."
In my opinion, this is not a correct representation of the content of the two studies. Claquin et al. (1999) provide a Mean Mineralogical Table (MMT) on the average mineral composition of 25 arid soil types. Even though the eight minerals (not six, since fractions of feldspar and gypsum were provided as well) in the table are main minerals found in soils, the fact that there are only eight minerals in the MMT is rather caused by the lack of available measurement data on the mineral composition of soils, when the study was conducted. There are other important minerals in soils, which also can have relatively high fractions, at least regionally, like chlorite, palygorskite, or halite. In a recent study, a new data set with the fractions of 12 minerals in soil was provided (Journet et al., 2014).
Sokolik and Toon (1999) studied how the state of mixture of hematite with other minerals affects the absorptivity of soil dust particles, which is important for their radiative effect. They did not study the mineralogy of dust in general, though.
Having said this, the paragraph in the Introduction with the statement on the two studies belongs to the part that could be removed altogether.

We agree with the reviewer's comment. Text has been removed (ACPD online version, P19185, L12 – 14)

3. Page 19189, line 27: How were the values for the size mass fraction **s**p of the accumulation and coarse mode derived? The original GOCART model by Ginoux et al. (2001) was based on a discreet bin scheme with an upper limit of 6 **μm** particle radius, and **s**p for clay and silt were slightly different to the values chosen here. This should be explained more. The parameters for the log-normal size distributions of the modal aerosol scheme used in the present study should be provided explicitly as well, for reasons of reproducibility. These are important parameters, since they essentially determine the emitted size distribution of dust, and, in turn, fallout rates and how much dust mass is being transported to remote regions.

We have changed the text as the reviewer suggested. Revised manuscript, P6, L17 – 31:

The original GOCART emission scheme was coupled with the eight-bin aerosol model. But in this study WRF-CHEM is configured with the Modal Aerosol Dynamics Model for Europe (MADE) and Secondary Organic Aerosol Model (SORGAM) aerosol model (Schell et al., 2001; Ackerman et al., 1998). MADE/SORGAM uses the modal approach with three log-normally distributed modes (Aitken, Accumulation, and Coarse) to represent sulfate, nitrate, ammonium, organic matters, black carbon, and sea salt. Mineral dust is assumed to have only Accumulation and Coarse modes. GOCART has been modified to couple with MADE/SORGAM. It calculates a dust mass flux from the surface (see equation (1)) assuming that, by default, s_p=0.07 for accumulation mode, which for emitted particles has the modal diameter D=0.6 μm, and width σ=2 μm; and s_p=0.93 - for coarse mode with D=6 μm, σ=2.2 μm. According to

MADE/SORGAM formulation the modal diameters change in atmosphere due to microphysical processes but widths of both distributions remain fixed. The total emission flux is adjusted using constant C in equation (1) to fit AERONET observations, as discussed by Zhao et al. (2010) and Kalenderski et al. (2013).

4. Page 19194-19996 and Figure 3: The description of evolution of the meteorological features in the regions in relation to the dust storm refers to the location of those conditions in the various countries of the region. Could the authors include the borders of the countries also in the maps shown in Figure 3, like it is done for Figure 1 and 2, if the plot program allows this? This will make it easier for the reader to follow the description in the text.

Figure 3 is corrected to show the political boundaries (Revised manuscript, P45)

5. Page 19199, lines 24-29: The authors present an estimate about the numbers of dust storms, where the dust plume covered more than 20% of the Middle East area. It is not clear, though, how this number was exactly derived. The link to the Image of the Day published by the NASA Earth Observatory is not sufficient as description of the data source and of the methodology for someone who wanted to reproduce this result. The authors should provide a more detailed description of the analysis for this part (in the Methodology section of the paper).

The text (revised manuscript, P14, L4 – 16.) has been modified as follows:
In this paper we have been interested in the total frequency and spatial distribution of severe dust events over the Arabian Peninsula and the Red Sea region. For this purpose we choose to analyze the NASA aerial photos because we believe that this resource is not fully exploited yet. The development of full-scale dust storm tracking software to run on existing aerosol retrievals and satellite images is relevant and interesting, but is beyond of the scope of the current study. We counted dust events based on their extent and optical depth estimate. We found that for the entire region the number of extended dust events reaches about 20 for the period of observations. The number of specific events in a particular region, e.g. over the Red Sea, reaches 6-8. The number of regional storms is consistent with the results of the previous studies (e.g., Rezazadeh et al, 2013 and Prospero et al., 2002) and our estimates using observations from the sparsely distributed AERONET stations.

6. Page 19204, line 17-18, and Figure 13: The authors write, "... aerosols exert a cooling or warming influence on the climate ..."

This is not wrong, but the effect is not just on climate, but on the atmosphere and the surface in the context of weather. The study itself does not analyze climate. Instead it analyzes the effect of dust aerosols related to a weather event. Thus, I would write "... aerosols exert a cooling or warming influence on the atmosphere and at the surface ...
Equally, in the caption of Figure 13, replace "Positive values correspond to the

heating of the climate system” with “Positive values correspond to heating” or with some other phrasing.

We agree. The text has been corrected as proposed (Revised manuscript, P55, L4 – 5)

7. Section 3.4: It would make it easier for the reader, if the authors summarized the values for the domain averages of the radiative effect for shortwave, longwave, and net radiation at the top and bottom of the atmosphere in an additional table.

We have summarized the domain average aerosol direct radiative effects in the new table (Table 3) as suggested (Revised manuscript, P42).

Typos

1. Page 19194, line 2 and 3: write: “ERA-Interim uses an improved atmospheric model ...”

The typo has been corrected (Revised manuscript, P10, L3)

Response to Review 2

This study presents a case study of dust event that occurred during 18-29 March 2012 over Arabian Peninsular using WRF-chem model with the GOCART aerosol option. Their model simulation successfully captures the strong dust event over the Arabian peninsular during the period also captured by the Satellite and AERONET remote sensing observations. They also estimated the radiative effect of dust event at surface is -10W/m2. In general the study may contribute to better understand the role of the dust storm over the region, but the paper still needs some major issues to be considered for publication.

We have used the WRF-CHEM model with the GOCART dust emission scheme. For calculating aerosol microphysics in this study we have used the Modal Aerosol Dynamics Model for Europe (MADE). In this case-study we have aimed at quantifying dust aerosol impacts associated with aerosol mass generated during the dust storm, dust transport and deposition. These characteristics are not measured in this region and are not well known.

The validation of the dust AOD is shown in Figure 8 and 9. How about emission, deposition, mass concentration? Are MODIS and AERONE the only available observations for the time and region? Evaluation of simulated dust would be the most challenging part of modeling study, however authors should put more effort on validation and they need to add more discussion about the uncertainly of the model results.

The validation of model aerosol output is challenging over the Arabian Peninsula because of aerosol insufficient observations. This was discussed in the introduction. Moderate-Resolution Imaging Spectroradiometer (MODIS) is the most trusted aerosol sensor on the NASA Terra and Aqua satellites that provides aerosol optical depth. Aerosol Robotic Network (AERONET) is a global network of ground based CIMEL robotic sunphotometers that retrieves aerosol optical depth for multiple wave-lengths and is the most reliable ground-based aerosol network. As AERONET sites are sparse over the Arabian Peninsula, we have established our own AERONET site at the KAUST campus, which is the only one at the Arabian west coast, and used those observations in this study. The direct observations of dust emission and deposition in this area are not available. However, the aerosol optical depth provides a reliable constrain to aerosol amount as it could be converted to aerosol loading provided we can obtain the aerosol specific extinction coefficient.

They compare WRF meteorological field with ERA-I reanalysis. It seems model generally capture the reanalysis, but I noticed that the WRF strongly overestimates the surface pressure on May 19 (Fig. 2e-f). The discrepancy is important since the difference shall influences the dust emission, deposition, and loading in Figure 3,5, and 9. It should be improved and discussed in the manuscript.

Erroneously we have used the same field for both March 17 and March 19. We have corrected this (Revised manuscript, P44). In new Figure 2 simulations compare with observations extremely well.

The text is lengthy and it needs to be greatly improved. First, the 6-page long introduction provides wide review of dust modeling, but many of them are not necessary for this study, rather they may distract the focus of this paper. These redundant texts appear in many other places especially in results sections. Although improving manuscript is the authors' responsibility, I will give some example as follow:

We have shortened the text as proposed:

Introduction, Section (1)
ACPD online version, P19183, L16 – P19184, L3: Text removed
ACPD online version, P19184, L10 – 12: Text removed
ACPD online version, P19185, L10 – 29: Text removed
ACPD online version, P19186, L8 – 11: Text removed
ACPD online version, P19186, L1 – 7: Text corrected (Revised manuscript, P3, L8 – 14)
ACPD online version, P19186, L11 – 13: Text corrected (Revised manuscript, P3, L23 – 25)

Methodology, Section (2)
ACPD online version, P19189, L10 – 14: Text removed
ACPD online version, P19189, L26 – 28: Text removed
ACPD online version, P19190, L1 – 9: Text corrected (Revised manuscript, P6, L17 – 31)

Results, section (3)
ACPD online version, P19196, L13 – 18: Text removed
ACPD online version, P19196, L20– 22: Text corrected (Revised manuscript, P11, L30– 31)
ACPD online version, P19196, L27– 28: Text corrected (Revised manuscript, P12, L4 – 5)
ACPD online version, P19198, L4 – 7: Text corrected (Revised manuscript, P13, L4 – 6)
ACPD online version, P19198, L15 – 22: Text corrected (Revised manuscript, P13, L12 – 14)
ACPD online version, P19199, L9 – 14: Text removed
ACPD online version, P19200, L11 – 12: Text corrected (Revised manuscript, P14, L23 – 25)

1. P19198, L15-22: The case in this sentence is for the Asian dust. What's the purpose of comparison with yours?

ACPD online version, P19198, L12 – 22: Text has been corrected (Revised manuscript, P13, L12 – 14)

2. P19199, L15-P19200, L4: This is not result. Suggesting remove it.

Here we estimated the amount of dust deposited to the Red Sea annually. We consider this an important result, as this is the first estimate of dust input to the sea drastically needed for biological studies. We believe we have to report this result.

3. P19201, L8-P19201, L11: This sentence is not relevant.

ACPD online version, P19201, L4 – 11: Text corrected (Revised manuscript: P15, L12 – 15)

4. P19201, L13-P19202,L5: This sentence is not result. It could be removed.

ACPD online version, P19201, L22 – 23: Text removed
ACPD online version, P19202, L3: Text removed

5. P19202,L15-P19202,L19: Same. Not relevant for result section.

ACPD online version, P19202, L11 – 15: Text corrected (Revised manuscript: P16, L7 – 9)
ACPD online version, P19202, L15 – 19: Text removed

6. Same for Section 3.4: The entire section can be greatly improved by removing text that discusses previous studies.

The text has been improved and shortened as proposed:

ACPD online version, P19204, L18: Text corrected (Revised manuscript: P18, L1)
ACPD online version, P19206, L11– 16: Text removed
Text added (Revised manuscript, P20, L4)
ACPD online version, P19207, Line 20 – 24: Text removed
ACPD online version, P19209, Line 2 – 12: Text removed

Yong-Seung and Ma-Beong (1996) should be Chung and Yoon (1996)?

The reference has been corrected (Revised manuscript, P2, L9 and 14)